

SINGLE-PHASE MOTOR IDENTIFICATION, SELECTION, AND APPLICATION  
PRINCIPLES

December 1, 1948

Objectives to Enable the Electrification Adviser

1. To identify the four most generally used types of single-phase electric motors.
2. To select the most suitable type of single-phase electric motor for a specific installation or machine.
3. To select a suitable type and size of single-phase electric motor for general purpose use under various practical conditions.
4. To install, adjust, care for, and maintain an electric motor.
  - A. Cleaning and oiling.
  - B. To reverse the direction of rotation in the four types of motors.
  - C. Care of brushes (in brush-type motors) and armature commutator.
  - D. To select and attach extension cords and switches.
  - E. To provide adequate service extension to supply power to the motor.

References

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3. "The Small Portable Motor." 4-page leaflet reprint. REA, USDA, Washington, D. C.
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THE HISTORY OF THE UNITED STATES

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8. "Fractional Horse Power Electric Motors." (Electrical Engineering Text Book). By Cyril G. Veinott, B.S. in EE: EE. McGraw-Hill Book Company, Inc., New York, New York.
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10. A Portable Motor for Farm Use. Bulletin 467. University of Georgia, Athens, Georgia.



## SINGLE-PHASE MOTOR IDENTIFICATION

### 1. Name Plate Information

- A. The first step in identifying any motor is to examine the name plate. In some cases manufacturers place the motor type on the name plate, which immediately identifies it. Information of greatest immediate importance includes horse power, phase, voltage, amperage, temperature rise, and speed of the motor. Single-phase motors are marked "Phase 1," or  $1\phi$ .

For general farm use, where single-phase current is supplied, the motor should be adjustable to operate on either 115 or 230 volts and have a continuous, rated load, operating temperature rise of 40 degrees C above the surrounding (ambient) temperature. (Note: Some motors have 50 degrees C temperature rise which is equal to 122° F). Most motors intended for general use are constructed for approximately constant speed under rated load. Speeds most commonly found are between 1725 and 1750 R.P.M. Motors are available with speeds slightly below 600, 900, 1200, 1800, and 3600 R.P.M. The exact speed depends on the number of magnetic poles and the operating slippage of the armature. The name plate will indicate normal speed at normal voltage and rated load current.

- B. Split-Phase Start Induction Motor: This motor has a smooth and regular shape so that the external appearance gives no indication as to whether it is a split-phase motor, a repulsion-induction motor, or a universal motor. Remove the cover plate at the front end of the motor (i.e., opposite pulley end) or the end bells. The absence of brushes indicates that it is a split-phase motor. If the name plate shows single-phase, the motor has no brushes, and is 1/2 h.p. or less in size, it is definitely a split-phase start induction motor. Note: Split-phase motors are not generally designed for operation on dual voltage. They are made to run on 115 volts or to run on 230 volts and when so constructed they cannot be changed to operate on alternate voltages. If the motor is disassembled it will be seen that the armature is a heavy copper frame (squirrel cage) and that it does not have an insulated wire winding. The induced armature currents, which are very heavy, flow through the copper core which resembles a revolving exerciser in a squirrel cage. Motors having rotors of this description are frequently called "squirrel cage" motors.

- C. Capacitor-Start, Single-Phase Induction Motor: This motor is distinguished by the capacitor, (i.e., condenser) generally mounted on the outside of the motor frame. It is housed in a cylindrical covering screwed to the frame. Note: Sometimes the capacitor housing is square or elliptical instead of cylindrical, and occasionally it is mounted inside the motor frame where it is not readily seen. Remove the cover plate or end bells if necessary to see the armature. Capacitor motors have no brushes and the name plate indicates one-phase. The rotor has no armature windings and is therefore the squirrel cage type. They range in size from fractional horse power to as much as 20



horse power. Some multi-phase motors have capacitors but the name plate will indicate the number of phases, and a capacitor-start induction-run motor is always one-phase. Two value capacitor motors have two capacitors, one used in the starting winding and one in the running winding. This motor will be discussed later. Its starting principle is identical to the single-value capacitor-start induction run motor. If the motor is disassembled it will be seen that the armature is a heavy copper frame (squirrel cage) and that it does not have an insulated wire winding.

Both split-phase and capacitor-start motors have a centrifugally operated snap switch in the starting circuits. This switch connects and disconnects either the starting winding of a split-phase motor or the capacitor (condenser) and starting winding in a capacitor motor. When the motors are stopped or turning below a given speed the switch is closed connecting the line current to the starting windings and the capacitor. When speed increases to a factory-determined amount the switch opens by centrifugal action and the motors operate as induction motors (i.e., squirrel cage); that is, the split-phase starting windings or the capacitors and starting windings have no further influence on the motor's operation. (Note: In a heavy-duty capacitor motor there are two capacitors, only one of which is used with the starting winding. The other is always connected to the running winding and improves the torque characteristics and the power factor of the motor). When the motor speed is reduced below a given R.P.M. the centrifugally operated switch closes automatically. If the load is the cause of the reduced speed the starting windings and the capacitor increase the motor torque, when the snap switch cuts them in. This sometimes enables the motor to rebuild its lost speed and to continue in operation at rated speed. Single-phase induction motors cannot start unless a starting winding, a capacitor and starting winding, or a wound rotor (repulsion motor) are provided to cause the motor to start revolving. Thus the three types of motors obtain the names, split-phase start, capacitor-start, or repulsion-start induction motors. (Note: A capacitor motor uses a split-phase to obtain starting torque. The electrical effects of the capacitor is to increase the angle between the magnetic fields of the starting and running windings from  $30^{\circ}$  to  $90^{\circ}$ . This accounts for the increased starting torque characteristics of capacitor motors).

- D. Repulsion-Start Induction Motor: This motor is identical in external appearance to a split-phase motor and to some styles of universal motors. This type of motor may be distinguished from the first two motors discussed by its brushes and coil-wound armature. Remove the cover plate or end bells if necessary. The first point of identification is to check the armature to see if it has been wound. A universal motor also has a wound armature and brushes but the brushes are stationary. Consequently, the second point is to determine whether the brushes are movable and lift or not. If they are movable and can be lifted and the



name plate indicates one-phase, the motor is a repulsion-start induction motor.

Some manufacturers make repulsion-start induction motors with brushes that are always in contact with the armature commutator, but provide a movable shorting ring which shorts the armature commutator segments, making in effect a squirrel cage of the wound armature. Other manufacturers provide both a shorting ring or necklace and brushes which lift out of contact with the commutator. The shorting device and brushes are operated by a centrifugal device that has small weights which move outward as the armature speed increases, activating the device and causing the brushes to lift and the ring to make contact, shorting the commutator segments when the motor reaches a certain speed. It then becomes an induction motor and in effect the rotor a squirrel cage.

The armature of a repulsion-start induction motor is wound with insulated wire, forming coils, the ends of which are attached individually to the segments on directly opposite sides of the armature. Armature coils are found in both repulsion-start and universal motors. Consequently, the repulsion-start motor is identified by the centrifugally operated shorting device, brushes which can be shifted, or both, and not entirely by the fact that it has a wound armature or nonlifting brushes.

- E. Universal Motors: This type motor may be similar in external appearance to both split-phase and repulsion-start induction motors. Therefore, the cover plate or end bells must be removed to identify it unless the name plate specifies the type. This motor is very similar in internal construction to the repulsion-start motor because it has brushes and an armature wound with insulated wire coils. The identifying differences are that the brushes are always stationary and there are no shorting rings (necklaces) or centrifugal devices.

Universal motor frames may be very similar in external appearance to the other motors discussed. In most cases, however, they are mounted in housings designed to fit or form the frame of the machine which they are intended to operate. Typical examples are vacuum cleaners and calculating machines which are generally driven by universal motors.

Another method of identification is to connect the motor to a current supply and observe its speed. Without load, a universal motor may reach a speed of 3,500 to 10,000 or 15,000 R.P.M. and the distinct whine of the motor indicates its high speed. A slight load, such as friction on the motor pulley, will greatly reduce its speed. This reduction in speed with slightly increased loads is direct evidence that the motor is a universal motor. Vacuum cleaner motors are the universal type. A change in the volume of air passing through the machine will make a noticeable difference in the motor speed.



## 2. Selection of Electric Motors for a Specific Installation or Machine

- A. What Machine Characteristics Determine Motor Requirements?
- B. What are the operating Characteristics of Split-Phase, Capacitor-Start and Repulsion-Start Induction Motors?
- C. What Kind of Bearings Do Motors Have?

The selection of an electric motor is determined by the type of current and the voltage available, the purposes for which the motor is to be used, and the horse power and speed desired. On most cooperatives the members use only single-phase current, the exception is generally in irrigated areas where three-phase current is made available for use on motors ranging in size from 10 to 50 h.p. In making a selection, the following three conditions should be carefully determined.

- (a) Horse power and speed requirements of the machine to be driven and the task to be done.
- (b) A thorough study of the machine to be operated and the load (torque) characteristics of the machine when running empty and at rated capacity of operation. Maximum starting, accelerating, and full speed power demands under all conditions should be fully determined.
- (c) The current specifications including voltage, voltage fluctuation, if any, the number of phases available, must be obtained (i.e., one, two, or three-phase.)

### A. What Machine Characteristics Determine Motor Requirements?

Farm machinery and equipment ordinarily turned by hand can be operated with a small electric motor at a cost range of one cent to five cents per hour for electricity. The small motor may be put to a practically unlimited number of uses on the farm to bring about a saving in time and labor and to reduce investment in new equipment. Hand labor cannot compete economically with low cost electric power.

To fully understand how motors meet practical operating conditions, it is necessary to divide any load into three parts. Each of these parts may vary separately and independently from each other over a wide range. These parts are designated as (1) starting load, (2) accelerating load, and (3) full speed load. Before selecting the motor for any particular use, the characteristics of the machine which it is to drive or the task which it is to do must be analyzed as above.

#### (1) Starting Load.

Some driven machines start with practically no load, and the full load develops only when full speed is reached. With other machines, there is some load when starting, but the

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load increases as the speed increases. In still other cases, the machine starts under full load. Examples of machines having each of these characteristics are:

- (a) No starting load - Fan, small toolgrinder
- (b) Some starting load - ensilage cutter
- (c) Full load at start - Piston type water pumps, cream separator.

(2) Accelerating Load.

When started, the machine or tool must be brought up to full speed. This is the accelerating load of the machine and is determined by the friction between the working parts, the inertia of the working parts, and the increased work done by the machine as the speed increases. A cream separator and a heavy fly wheel are hard to start. They are excellent examples of great inertia. In general, heavy objects have greater inertia or resistance to change in speed than light objects. In the case of a blower fan, the load increases as speed increases because more air is being moved.

(3) Full Speed Load

This refers to the load of the machine on the motor after it has reached full speed and the machine is running at normal speed and capacity. Temporary overloading of the motor must also be included. The motors on such machines as ensilage cutters, hammer mills, and hay balers, may be subject to frequent and rather large temporary overloads.

TORQUE

Turning effort is usually expressed in terms of "torque." Torque is measured in feet pounds (pound inches) - force x length of leverarm) of work required to rotate a load. It is also used to measure the power of the motor in pulling on the belt. Engineers, mechanics, and electricians divide the three torque loads discussed under A, B, and C above as follows:

- |                   |  |
|-------------------|--|
| Starting Torque   | - Turning effort required to start rotating a load.                                      |
| Pull-up Torque    | - Turning effort to bring the load up to the proper operating speed after it is started. |
| Break-down Torque | - The size of load that will reduce motor speed and eventually stall the motor.          |

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The size of motor required to operate any machine depends on the three types of loads and the duration of the maximum load. Since the types of electric motors generally available have different operating characteristics, the type must be matched to the load requirements to obtain satisfactory operation.

Since most farmers have only single-phase electric service, the following discussion will cover single-phase motors only. These motors are made in several designs, but only two of these designs are particularly well adapted to general farm use. They are the capacitor-start and the repulsion-start induction-run motors. When both the machine and motor characteristics are known, the proper size and type of motor can be selected.

B. What Are The Operating Characteristics of Split-Phase, Capacitor-Start and Repulsion-Start Induction Motors?

The three types of single-phase motors best suited for farm use are

- (1) Split-phase induction-run motor
- (2) Capacitor-start induction-run motor
- (3) Repulsion-start induction-run motor

There are several other types of single-phase motor, but they are not generally as desirable as the three listed above.

- (1) Split-phase induction motor.

A split-phase motor is the lowest in first cost of the three types of motors. Its operating characteristics are the least desirable of the three. Its greatest starting torque is approximately 230 percent of its full load torque, and its pull-up torque is approximately 200 percent of full load torque. These are too limited when compared to the starting and pull-up loads of many farm machines. Consequently, the split-phase motor should not be used on machines that are hard to start or to bring up to full speed.

The split-phase motor has a breakdown torque of approximately 230 percent of its rated full speed torque. This type motor requires a relatively large amount of current to start and come up to full speed. The starting current may be seven to nine times the full load current. This motor is not made in sizes over one-half horsepower because of the excessive starting and accelerating current.

This high starting current demand is undesirable in many situations because very large wires are necessary if the motor is to have its full, though limited, starting ability. When improperly installed, or when used on circuits in buildings with too small wiring, it causes lights to flicker

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when starting. You will note in Table I that the starting current required by this motor is two and one-half times that of a repulsion-start induction motor, yet it has slightly less than one-half the starting torque.

## 2. Capacitor-Start Induction Run Motors

Capacitor-start, induction motors are somewhat more expensive than split-phase motors. The capacitor type motor can be distinguished from the other types by the cylinder containing the capacitor which is normally mounted on top of the motor.

The capacitor-start motor has a starting torque of approximately 435 percent of its full load torque. This is nearly twice the starting torque of the split-phase motor. It has a pull-up torque of approximately 250 percent and a breakdown torque of approximately 265 percent of full load torque. Its greater starting torque makes it a better motor than the split-phase type for medium to hard starting loads. The maximum starting current is from four to six times the full load current. In Table I you will see that this starting current is approximately one-half that of the split-phase motor on similar loads, and varies from six to seven times rated load current.

Motors of this type are manufactured in fractional horsepower sizes and integral horsepower sizes up to 20 horsepower. (Note:  $7\frac{1}{2}$  to 10 horsepower is limit on REA lines). However, power distributors generally limit the maximum size of motors on single-phase lines to either 5 or  $7\frac{1}{2}$  horsepower.

A modification of the capacitor-start motor is the capacitor-start capacitor-run motor. It has about the same operating characteristics as the capacitor-start motor, and is manufactured in the same sizes but must be specially ordered from the manufacturer. This motor has two capacitors, one in the starting winding and one in the running winding. It is particularly valuable when large peak loads occur frequently in the operation of a machine. It is not recommended for general farm use because of its limited production and scarcity on the local market.

## (3) Repulsion-Start Induction Motors

The repulsion-start induction motor is really two motors built into one frame. This motor starts as a repulsion motor, but when the necessary speed is reached, it operates as an induction motor. The repulsion motor has a very high starting torque, and when combined with an induction motor, makes a very adaptable motor for general farm use. When starting as a repulsion motor, it has a torque of approximately 550 percent of its normal full load torque. This great ability to start a load is of importance to farmers, as many farm machines require a high starting torque. It has a pull-up torque of approximately 225 percent, and a breakdown torque



of about 265 percent of its normal full load torque.

The starting current for this motor is very low as compared with the other two types of motors. It has a starting current ranging from two to four times its full load current. This is an added advantage, as smaller wire sizes can be used to supply the current to this motor as compared to the other types on similar loads and at equal distances from the meter or distribution panel.

Many farmers will use the same motor on several machines; therefore, a motor should be purchased for general use that is capable of delivering maximum power in starting, pull-up and breakdown loads. The repulsion-start induction motor is recommended as best suited to fill these requirements. Consequently this motor is highly recommended where it is to be put to general farm use. It is manufactured in fractional and integral horsepower sizes. It also is subject to the same general limitations of five or seven and one-half horsepower by the power line operators.

Machines to which the repulsion-start induction run motor are best suited include a cream separator, hammer mill, ensilage cutter, and large volume blower fans.

When a motor is purchased for use on one machine only, it should be selected to most nearly fit the characteristics of that machine.

#### (4) Other Types of Motors

There are several other types of motors, none of which are as adaptable to general farm use as the three previously described. The universal motor is probably most commonly used. It gets its name from its ability to operate on either alternating or direct current. It depends on its load to control its speed, and consequently has very poor speed regulation. Its main application is for small household appliances, such as a food mixer or vacuum cleaner. It is not recommended for general farm use.

#### (5) Fractional Horsepower Motors

Fractional horsepower motors are those rated at less than one horsepower. Such motors are made in split-phase, capacitor, and repulsion-induction types. They can be operated on 115 volts, but 230 volts give better operating results for one-half horsepower or larger sizes. Wiring changes within the motor must be made to change from 115 volts to 230 volts, or vice versa.

1. The first part of the document discusses the importance of maintaining accurate records of all transactions. It emphasizes that proper record-keeping is essential for the transparency and accountability of the organization. This section also outlines the various methods used to collect and analyze data, ensuring that the information is reliable and up-to-date.

2. The second part of the document focuses on the financial aspects of the organization. It provides a detailed overview of the budget, including the projected income and expenses for the upcoming year. This section also discusses the various financial risks and how they are being managed to ensure the organization's financial stability.

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(6) Integral Horsepower Motors

Integral horsepower motors are of one horsepower or larger size. They may be obtained in 1,  $1\frac{1}{2}$ , 2, 3, 5,  $7\frac{1}{2}$ , or 10 horsepower sizes. Split-phase motors are not made in sizes larger than one-half horsepower, but both capacitor-start and repulsion-start induction motors are generally available in all sizes. Some cooperatives may not permit the use of  $7\frac{1}{2}$  or 10 horsepower motors on their lines. When necessary, the larger motors can also be made portable by attaching them to a two-wheeled cart. (See REA Motor Cart construction plans). Note: A recent trend has been to eliminate the terms "fractional" and "integral" and to list motors of one horsepower or more as "large" and those less than one horsepower as "small" motors.



AVERAGE STARTING TORQUE, PULL-UP TORQUE  
BREAK-DOWN TORQUE, EFFICIENCY AND THE MAXIMUM  
STARTING CURRENT OF SOME SINGLE-PHASE MOTORS

TABLE I

	REPULSION START INDUCTION	CAPACITOR START INDUCTION	SPLIT-PHASE START INDUCTION
<b>**FRACTIONAL HORSEPOWER MOTORS</b>			
Starting Torque	550%	435%	230%
Pull-Up Torque	225%	250%	200%
Break-Down Torque	265%	265%	230%
Efficiency	56%	65%	65%
***Maximum Starting Current (Percent full load current)	200 to 400%	600 to 700%	700 to 900%
<u>Locked rotor current:</u> <u>1/4 HP motor</u>	<u>13 Amps</u>	<u>19 Amps</u>	<u>32 Amps</u>
<b>*<u>INTEGRAL HORSEPOWER MOTORS</u></b>			
Starting Torque	400 to 450%	250%	
Pull-up Torque	200%	200%	
Break-Down Torque	235%	210%	
Efficiency	81%	78%	
***Maximum Starting Current (Percent full load current)	200 to 400%	600 to 700%	

\* Taken from information on five horsepower single-phase motors published by Century Electric Company, St. Louis, Missouri

\*\* Taken from information published by Century Motor Company

\*\*\* Taken from "Electrical Engineering" - 1939 issue - by E. E. Kinberly



### 3. The Selection of the Size and Type of Motor for General Purpose Use

In the selection of a motor for general farm use there are three major factors that will determine the size and type of motor to purchase. The first is the maximum horsepower that will be required to operate the various machines or to do the necessary work. If the tasks cover a wide range of required horsepower, it may be necessary to have two or three or even more general purpose motors. In cases where the range of required power extends from  $1/4$  horsepower to  $7\frac{1}{2}$  horsepower, it would be well to group the tasks according to the approximate power required by them; that is, those that require less than  $3/4$  horsepower, those requiring from  $3/4$  to 3 horsepower, and those requiring 3 horsepower to  $7\frac{1}{2}$  horsepower. The number of machines to be operated in each power group will then determine whether the purchase of a motor for each group can be justified. Frequently, there are several tasks requiring  $1/2$  horsepower or less. Thus a small motor of  $1/3$  or  $1/2$  horsepower can readily be justified.

There are comparatively few tasks requiring from  $1/2$  to 1 horsepower that occur frequently enough to justify the purchase of a general purpose motor for this particular power range. Thus it might be wise to select a 3 horsepower motor to do the tasks between  $3/4$  and 3 horsepower, thus reducing the investment in motors. If the maximum power required is  $7\frac{1}{2}$  horsepower, then this size motor could be used on power tasks of 3 horsepower or more. However, few farms will require more than a 5 horsepower motor. In that case, a 2 horsepower motor or even a 1 horsepower motor might well be selected in place of a 3 horsepower motor, and the 5 horsepower motor used on all tasks above the 1 or 2 horsepower motor. Each general purpose motor selected would do all the tasks above the ability of the next smaller motor.

Electric motors should be operated at or near rated load. They can be safely overloaded 15 percent; that is, a service factor of 1.15 can be used in selecting motor size. This is more important on large motors of 25 horsepower or more because of purchase cost.

It should be understood that all motors draw only the amount of power required to energize the field and armature coils, plus the amount required to overcome bearing friction and to do their work. Thus a motor working at partial load but normal speed draws less current than one at full load. This is due to the generating characteristic of the motor when in motion; that is, the power entering the motor is opposed by the voltage generated by the armature as it revolves. This opposition voltage (back electromotive force) reduces the total current drawn by the motor as the speed increases or when working below rated load. The motor is less efficient as the load decreases because the current necessary to energize the coils is constant regardless of the load. Therefore, a five horsepower motor should not generally be used on work requiring less than 3 horsepower. On the other hand, there are occasions where a five horsepower motor could well be used on a one horsepower task for a limited time and the loss of efficiency would not be as serious as the investment in a motor for which there was little use.



The second consideration is the type of loads that must be handled by the general purpose motor. Obviously the motor must do the most difficult task as well as the easiest. It will be necessary to study each machine to be driven and each task to be done to determine the power demands when starting the machine, when acceleration is in progress and when operating at the rated speed and capacity of the machine. Since even small machines vary widely in their power requirements, the split-phase motor is practically always eliminated for general purpose usage.

The third consideration has to do with the location and housing of the motor. If the tasks to be done are a long way from the meter, it is obvious that a motor which draws the least current is most desirable. This means that distribution wires between buildings need not be excessively large if the motor demanding the least power for starting is selected.

If the motors are indoors and protected from the weather and operate in clean air they can be open frame construction. If they are used outside or where falling water may reach them they should be drip-proof and/or splash-proof. When they are operated in dusty conditions such as in feed rooms, haymows, or poultry runs, they should be dust-tight, explosion-proof construction. This will not only prevent explosions and dust fires but will also lengthen the life of the motor. It will prevent dust and dirt from clogging the air passages and causing the motor to overheat, and it will protect the bearings by keeping foreign material out of them.

#### 4. Care, Maintenance, Adjustment and Installation of the Electric Motor.

- A. Heat, dirt, dust, excessive oil, salt, acid, and water are the worst enemies of the electric motor because they result in damage to the insulation. Motors should be placed in a clean, dry, and protected location where they do not come in contact with dirt or moisture. If excessive dust, moisture, and foreign matter cannot be shut out, then totally enclosed motors which are of explosion-proof, splash-proof and/or drip-proof construction should be used. Drip-proof motors are not splash-proof but some manufacturers supply an extra cover which makes them splash-proof. Splash-proof motors are not drip-proof but some makes can be modified to make them drip-proof.

The fan mounted on the rotor shaft of an open motor pulls either dust or moisture into the motor with the air which cools the motor. In time some dirt and dust will accumulate even when a motor is located in a comparatively clean, protected spot. Dust accumulations restrict air passages, preventing the fan from blowing sufficient air through to cool the motor. This results in a hot motor which will damage the insulation if the heat is not removed. The dust should be blown out whenever the motor is inspected or oiled by using compressed air from a pressure tank, with a vacuum cleaner or with a hand air pump. Only a few drops of oil should be used at one time to lubricate a sleeve bearing. Excessive oiling may



result in saturating the coil insulation, causing it to deteriorate and eventually break down. Excess oil also tends to collect dust. Oiling at 60-day intervals is sufficient for sleeve bearings on motors in everyday use. Those used at infrequent intervals should probably be oiled only once or twice a year, say on January 1 and July 1, to make it easy to remember the servicing dates.

Oil is used only with sleeve bearings. No. 10 W automobile oil is recommended for use with small motors. These bearings have an oil wick which is packed around the shaft and in the reservoir. It soaks up the oil and keeps the shaft lubricated at all times. When ball or roller bearings are used they generally are greased for "life" at the factory. "Life" is generally considered to be five years. Consequently, the bearings should be checked to see if they contain sufficient grease at five-year intervals. A special ball bearing grease should be used for this purpose. It can be obtained from electrical supply houses. Large sleeve bearing motors have oil reservoirs which generally can be inspected by removing an "oil plug" to see if the oil is up to the proper level. These reservoirs are beneath the bearing and located in the end bells. Another "oil plug" at the bottom of the reservoir is provided for draining and cleaning out the reservoir. Use No. 20 W automobile oil in these larger motors. This heavier oil is required because of the weight of the armature and the pressure of the shaft on the bearings. Always check the oil reservoir locations to see that they are beneath the shaft. If necessary, revolve the bells (brackets) in the stator until they are in such a position that the reservoirs are beneath the shaft when the motor is in position for running.

A motor has a uniform turning movement about the shaft. Because of this, there is little shock or vibration on the motor bearings. If a motor is properly mounted on a rigid support, most of the wear on the bearings will be that due to the weight of the rotating parts and the pressure due to belt tension and motor torque. A bearing is designed for a definite load or pressure on its surface. If this load is exceeded, rapid wear results. A belt that is too tight will overload a bearing and cause abnormal wear and undue heating. For this reason, a belt should be just tight enough to prevent slipping. (V-belts require less tension to prevent slippage than do flat belts.) Bearing heat is caused by friction and should not be confused with the heat of the motor during normal operation.

Sleeve bearings are made of brass, bronze, or babbitt. Due to the cost of construction ball bearing motors cost more than sleeve bearing motors, but this additional cost is offset by the less attention they require.

Bearings are not only designed for definite loads, but are designed to take loads in only one direction. Consequently, a motor designed for horizontal mounting should not be mounted



with the shaft vertical nor in positions where the shaft will be off level. Motors for vertical or angle mountings must have a thrust bearing at one end of the shaft to support the armature. Vertical motors are normally built with ball bearings because the lubricating oil used on sleeve bearings drains away when they are in a vertical position.

Occasions will sometimes arise when a horizontal motor must be mounted overhead in an upside-down position, or possibly on its side in a horizontal position with the base mounted on a vertical wall. When this is necessary, the motor and brackets or bells must be removed and revolved a one-fourth or one-half turn so the bearing oil reservoirs are in their normal position below the bearings. This change is very important, as otherwise the oil can drain out, leaving the bearings without lubrication.

#### B. To Reverse the Direction of Rotation

Main pulleys on farm machines may rotate in different directions. The same motor is frequently used to drive several machines. If the motor cannot be properly located to obtain proper machine rotation, it may be necessary to change the direction of rotation of the motor. This can be done by the operator, but it requires a few minutes time and a knowledge of how to change the wires or brushes in the motor.

The split-phase and capacitor motors are reversed in direction by reversing the starting winding leads. Wiring changes are shown on diagrams under the cover plate where the cord attaches to the motor terminals, on the tags attached to each new motor or on the motor name plate. The repulsion-start induction motor is reversed by shifting the brushes in the direction of desired rotation. Marks inside the motor by the brush holder show the proper brush holder location for the desired direction of rotation. To reverse rotation, loosen the lock nut or bolt and rotate the brush holder so that the arrow on the holder and the mark on the bell flange are in line. Only a small movement of the holder is necessary. Relock the brush holder by tightening the locking device. (Generally a machine bolt and lock washer.) Manufacturers supply complete instructions with each type of motor for reversing direction of rotation.

Universal motors of the non-compensated type cannot be satisfactorily reversed because of poor operating commutation which causes the brushes to spark. Sparking damages both brushes and armature commutator since the sparks burn holes and rough spots in the carbon brushes and in the copper armature segments.

#### C. Care of Brushes and Armature Commutator

When brushes are used they tend to wear. Occasionally they have to be replaced. They can be purchased from dealers and/or electric supply houses if the information on the name plate



accompanies the order. Under some conditions the armature commutator on which the brushes press when the motor is starting become worn or irregular. This also causes sparking and rapid wear of the brushes. If the damage is slight, the roughness can be remedied with sandpaper while the motor is running (never use emery paper). The sandpaper should be placed over the end of a small, square and stick and then held in contact with the commutator (copper segments on the armature to which coil ends are fastened). By pressing lightly on the stick and moving it back and forth across the commutator, the surface can be made smooth and regular. If the commutator is too rough and pitted to be smoothed with sandpaper, the rotor should be removed from the motor, placed in a lathe and the copper commutator surface turned down until it is smooth.

D. To Select and Attach Extension Cords and Switches to Small Motors

Motors one-half horsepower or less in size and operating on 115 volts may be connected to convenience outlets simply by plugging in the extension cord. No control switch is necessary. Extension cords should have large enough conductors to carry the necessary current with less than a three percent voltage drop. On a portable motor the cord should also be long enough to permit considerable freedom in locating the motor and the machine it is to drive. On permanent installations, attachment cords should be just long enough to reach the outlet. They should also be located in a protected position to keep them from interfering with the work on the driven machine and to prevent unnecessary wear or mechanical injury. In some cases armored cable or conduit may be justified for protection to the cord and safety to the operators. Where such protective installations are made a control switch is essential.

Rubber or plastic-covered extension cords are essential for portable motors, and type S heavy-duty cord (rubber or plastic-covered) should be obtained for motors used in farm shops or other places where friction or wear are heavy and mechanical injury readily possible with light insulation.

Number 18 conductor cord or larger should be used on 1/4 and 1/3 horsepower motors. Half horsepower motors should be equipped with No. 16 conductor cord or larger. If extension cords longer than 12 feet are used, a check should be made to see that voltage drop caused by the cord does not exceed three percent at maximum starting current. (Use the wiring slide rule to check voltage drop on the extension cord.) The conductors in extension cords should always be stranded so the cord will be flexible and have less tendency to break with severe usage.

Conductors are fastened to field coil terminals in the terminal or connection box of the motor. Remove the cover plate to expose the terminals to which the motor winding leads are attached. Check the wiring diagram on the motor name plate or on the under-



side of the terminal box cover plate. This will show which leads to connect for either 115 or 230 volt current. The power leads bringing current to the motor are marked "Line."

Remove about 1/2-inch of insulation from each extension cord conductor. Remove the nuts and wrap the bare conductor around the terminal bolts (binding posts) with a right hand twist. This will aid in making good electrical contact when the nuts are screwed back in place. Brass or copper washers should be placed between the nuts and the bare conductor ends. This will prevent fraying of the conductor and also make a better contact. After fastening the cord, replace the cover plate.

Some connection boxes will have knockouts. The cord should pass through such an opening and be held in place with a box connector. Where knockouts are not provided the cord should enter through a groove and press tightly enough against the cord to remove any strain from the terminal bolt and cord ends.

Large motors require the same care in selecting the proper size conductor for connecting the motor to the source of power. Since most large motors operate on either 115 or 230 volt power, the wiring diagram showing the proper coil connections should be carefully inspected and the connections double checked. (If the wrong voltage is applied to the motor for the connections made, the motor will burn out, fail to start, or get up to speed.)

For safe operation with 230 or more volts, the motor must be grounded. If a three-wire cable is used, the white wire can be grounded to the motor frame at the terminal box. This grounds the motor back through the system to the yard pole and building ground rods of a polarized wiring installation. When a two-wire cable is used, the motor should be grounded at its immediate location. This can be done by attaching an end of a bare or insulated conductor to the motor frame and the other end to a ground rod or a pipe driven into the ground for at least eight feet near the motor location.

All motors, regardless of size, must be grounded when they are used in wet, damp places such as in dairy barns, milkrooms, basements (with or without concrete floors) or wherever water, wet feet, wet hands, water pipes and electric motors are used together. Electric drills should always be connected to ground through a three-wire extension cord. This is true of any metallic power device held in the hands when working with it.

With heavy cable, connections to the motor are generally made with solder-type lugs. The lugs fit over the terminal bolts, permitting a tight connection. Where no terminal bolts are provided, lugs are put on the ends of the motor leads and the proper lugs bolted together to make conductor and motor lead connections. Solder lugs are those requiring melted solder



in connecting them to the conductor. This is done by heating the lug and holding it in such a position that lead can be poured or melted into the recess formed for that purpose. When the reservoir is filled with hot lead, the bare conductor is inserted and held in place until the hot lead cools enough to hold it securely.

In some cases "twist nuts" or pressure type connectors are used. These are very satisfactory especially if the conductor cable is held fast to the motor with a box connector to take any strain on the cable and to protect the conductor connections.

Snap switches with overcurrent protection are available for small motors on 115 volt current. These switches may be mounted on the wall or on a bench. Toggle snap switches without overcurrent protective devices are frequently mounted directly on the motor frame. In other cases, ordinary light switches may be used. These are generally mounted on the wall as a part of the building wiring installation. When so arranged they control the flow of current to the convenience outlet to which the motor is customarily attached. Occasionally a light switch is used on work benches, or on the motor table to control the motor operated on 115 volts. In such cases the connection from motor to switch is generally permanently installed and an extension cord is used between the switch and convenience outlet supplying power.

#### E. Adequate Service Extensions

In many cases farmstead wiring was only partially completed at the time the farm system was energized. This may have been due to the high first cost of wiring or to lack of planning for future use. In such cases, it may be necessary to extend service from the meter to a building. At other times the building service may be in place but the conductors may be too small to carry the increased load without excessive voltage drop. In either case, it is essential that adequate sized conductors be installed to insure full voltage at the various power outlets. Again the wiring slide rule should be used to determine the size conductor necessary to supply the demand for power.

The first point to check is to measure the distance between the meter and the building served. This can be done with a tape measure or by walking between points and counting the number of steps if the stepper's "pace" is known.

The second point is to inspect the building distribution panel to see that the main amperage capacity of the panel is sufficient to handle the demand load of the equipment in the building. Next check the individual circuits to see if the circuit supplying the power is ample to carry the load demanded by the new equipment. In some cases a new circuit may have to be run because the installed circuits do not have sufficient capacity to take the new load. If a spare circuit is not available or the main circuit supplying the



branch circuits in the service panel is not large enough, a new panel of adequate capacity and sufficient circuits must be obtained. If a new circuit should be run, the distance from the service panel to the power outlet must be measured, the amperage demand of the new load determined and the proper size conductor selected to supply and maintain proper voltage under maximum permissible power demands of the load.

